Research Paper | Engineering | E-ISSN No : 2454-9916 | Volume : 3 | Issue : 5 | May 2017

STRUCTURAL CONDITION ASSESSMENT & REHABILITATION OF EXISTING STEEL FACILITY USING NON DESTRUCTIVE TESTS & LATEST CODAL PROVISIONS

Milap D. Shah [1] | Jigar Rana [2] | AnilKumar Kannauzia [3]

[1] Post Graduate Student, Parul Institute of Technology, Vadodara, India.
[2] Consulting Structural Engineer, Vadodara, India.
[3] Assistant Professor, Parul Institute of technology, Vadodara, India.

ABSTRACT

The existing codal provision for design of steel structure is based on limit state method and lots of research pertaining to its comparison with working stress method has been done. However, provision of handling design of existing steel structure which was previously designed as per working stress method, in current code is not elaborately addressed.

With this research, it is intended to formulate a procedure of refurbishing design of existing steel with use of latest code and future need. To achieve this, an existing steel structure facility with aggressive environment is considered. The case covers wind, seismic and temperature load effect on structure. Condition assessment of existing structure was carried out by visual inspection and various Non destructive tests (NDT) performed on random samples.

NDT test covers Ultrasonic thickness test, Hardness test and Coupon test on existing steel structure members, the change in design parameters and strength parameters. Analytical model of existing structure was created in STAAD Pro software, and design parameters as per existing strength identified through NDT were applied. Analytical results of failed members as per design procedure of latest code were studied and individual member wise refurbishment/ structural strengthening The analytical model of existing structure was further used to evaluate design results as per IS 800 1984 and IS 800 2007 before applying effect of NDT results to draw effect of existing loading condition and its effect on life of structure before indicating refurbishment and strengthening aspects.

KEYWORDS: Nondestructive test, Refurbishment, Steel structure, IS 800 2007, Limit state method.

INTRODUCTION

Currently the many existing steel structure facility in India which were designed as per working stress design method i.e. IS:800-1984. The current codal provisions i.e. IS:800-2007 was revised after many long time periods. Furthermore the new code have introduced many provisions first time which previous code had silent about this. Many existing steel structures facility were designed as per previous codal provisions. However the current code is not elaborate regarding the existing steel structures facility's condition assessment & rehabilitation to its extended life span.

The current code of practice have introduced many provisions such as the limit state method is introduced. Furthermore this method is related to strength & serviceability of the structural members. In additions separate deflection limits were provided for steel members. Block shear is considering while design the tension members. For the compression members different four buckling curves are introducing also different section types are also considering in design procedure. The codal provisions also describing the fatigue behavior, fire, earthquake & corrosion first time which the previous codal provisions had not described. (IS:800, IS:800-1984, 1984)

As the new codal provisions are introducing many criteria first time , but the codal provisions are not elaborating regarding the strengthening measurements requires for the existing steel structures which were designed as per IS:800-1984. So this research woks aim to find required changes in existing steel structure facility which is coming to its end of life period. so this steel facility is designing as per latest codal provisions to its extended life span what are the deficiencies is find & what will make the strengthening measures to its extended life span using latest codal provisions.

According to the AISC Steel design guide series 15 , it emphasis on the rehabilitation & retrofitting of the existing steel structures. Furthermore the AISC 15 also providing the assessment techniques & retrofitting methods related to the existing steel structures. (AISC, 2002)

In 2012 (Eric Wey, 2012) has mentioned in their research paper regarding the repair and retrofit of the opened frame steel structures. Their study is emphasis on the situations in the chemical & petrochemical steel plants repair and retrofit process. Furthermore the study is also emphasis on to provide economical & practical retrofitting techniques. And they have suggested various retrofitting techniques for the steel structures.

In 2012 ,the condition assessment of the existing steel structure facility were done by (ADINDA Chaerany, 2012) by NDTs in maintenance plant in Indonesia. The existing plant almost reaches to its design life periods. Hence the assessment of the plant is to observed the deteriorations in the plant, remaining life span , and what are the remedial measures are required is studied .

In this research paper study about what are the strengthening measures will require on the existing steel structure facility Which is coming to near its end of designed life period. The steel facility which is having the furnace facility, the furnace facility is working on very high temperature . Hence the temperature variation is taking place near the gantry girders having capacity of 5Tone & 2Tone. The research work is also considering on the effects of temperature variations on the existing structural members of the steel facility, hence temperature load is considering in this study.

This research work is doing the condition assessment of the existing steel facility with Non-Destructive Tests i.e. Ultrasonic thickness measurement, Hardness test & Coupon Test etc. Furthermore this NDTs data were using in the analytical model in STAAD.Pro software for analysis of existing steel facility & design as per latest codal provisions. This analytical model was showing a deficiencies in the members as per latest codal provisions and NDTs data. The deficient structural members were designed to its extended life span using latest codal provisions. In additions the research work also finding the utility ratios of the members in the steel facility, and observes the changes in the utility ratios with different design methods. And also finding the quantity of the structural steel in the strengthening measurements is requires was carrying out in this study.

METHODOLOGY

a) Preliminary survey

The research work was carried out for what are the changes will occurs when the existing structural members are analysis and design as per latest codal provisions. And what are the strengthening measures will required to fulfills as per latest codal provisions as well as to its extended life span. Hence the research work has been carried out in the existing steel facility by preliminary evaluations having done by visual inspections of the structural members in the steel facility. The preliminary survey are done to observed the existing conditions in the structural members i.e. corrosion on the members, deflection, load path ,dimension of the structural members, equipments information etc. The preliminary surveys is helpful for making plan of the existing steel facility as well as for the calculations for the analysis & design purpose. After the Preliminary survey was carried out the plan of the existing steel facility was made. The plan of the existing steel facility as shown in fig. 1

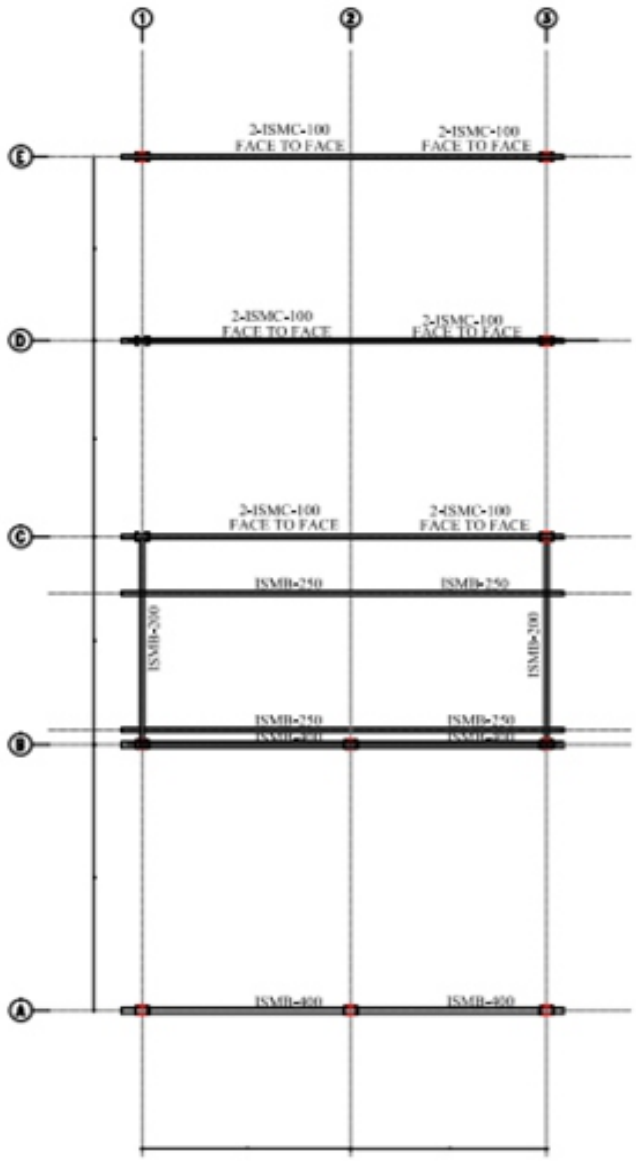

Fig.1 Plan of existing steel facility

Existing steel facility is 9.45 mt x 20.54 mt having Monoslope structure with minimum height is 7.80 mt & maximum height is 9.70 mt. The distance between grid 1-1 & 2-2 is 4.87 mt. & Distance between Grid 2-2 & 3-3 is 4.58 mt.

b) Detailed evaluation using Non-Destructive Testing

The detailed evaluation was carried out in this study for the detail evaluation of the existing structural members in the steel facility. Hence the Non-destructive Tests was performed on the structural members in the steel facility. The ultrasonic thickness measurement test , Hardness test, Coupons test was done in the facility. Before conducting Non-Destructive tests on the structural members the surface preparation was done on the structural members at testing points at 1.0 mt intervals.

i) **Ultrasonic thickness measurement :-** The ultrasonic thickness measurement test is carried out for the measuring the residual thickness in the existing structural members in the steel facility. In this research work UTG-III (Samsonic Make) used. The probe of the instruments is 10 mm Diameter, 5 MHz TR Normal Beam. The test method was conducting as per ASME sec-IIV (Div 1). The thickness reading data were taken on the Beams such as ISMB 250, ISMB 400 & ISMC 100 in the steel facility at 1.0 mt intervals. Similarly the thickness measurements reading were taken at columns ISMC 200, ISMC 150 , ISMC 75 at 1.0 mt intervals.

ii) **Portable hardness test:-** The portable hardness test is carried out for the taking the residual strength of the structural members in the existing steel facility. The portable hardness instrument MHT-100 (Samsonic make) was used in the research work. The testing methods was conducted as per A-370 standards. The hardness readings were taken same in the beams and columns where the Ultrasonic thickness measurement was done. As shown in fig.2 the NDTs were taken at 1.0 mt intervals on the structural members in the steel facility.

Fig.2 NDTs performed at 1.0 mt intervals

c) **Tensile strength test:-** The tensile strength test was done as per IS 1608-2005 to find out the tensile strength of the structural steel. Two samples from the structural members in the steel facility were taken. (IS:1608-2005, 2005)

d) **Analysis of existing steel facility & designed as per IS:800-2007 & NDTs Data.**

The existing steel facility was analysis & designed as per IS:800-2007 & NDTs data's. The NDTs data have studied and the minimum values from the NDTs have taken for the evaluation of the existing steel facility.

The load calculations were done for the analysis & Designed pf the steel facility.

i) Dead loads were calculated in the steel facility as per IS:875 (Part-1)-1987 having asbestos corrugated sheets as a roofing material having weight of 0.13 kN/Sq.mt.

Gantry cranes were also there in the facility having capacity of 5T & 2T .

ii) Live load calculation

The live load was considered as per Table-2 ,IS:875(Part-2)-1987 .

iii) Wind load calculation (IS:875 (Part-3)-1987, 1987)

- Basic wind speed = 44 m/sec for Vadodara city as per Appendix-A
- K1 (Risk coefficient) = 1.0 (as per Table-1, General structures)
- K2 (Terrain , height, structure height factor) = 0.88 (terrain category-3. class-B)
- K3 (Topography factor) = 1.0 (as per c.l.5.3.1, IS:875(Part-3)-1987
- Vz (Design wind speed) = Vb*K1*K2*K3
- Vz = 38.72 m/sec
- Pd (Design wind pressure) = 0.6*Vz^2
- Pd = 900 N/Sq.mt
- Pd = 0.9 kN/Sq.mt

a) wind load coefficient at roof as shown in Table.1

Table.1 Wind pressure coefficient for roof

Wind Angle		Cpe	Cpi	Cpe-Cpi	(Cpe-Cpi)*A-Pd
0°	H	-1	0.7	-1.7	-1.53
		-1	-0.7	-0.3	-0.27
	L	-0.5	0.7	-1.2	-1.08
		-0.5	-0.7	0.2	0.18
90°	H&L Apply	-1	0.7	-1.7	-1.53
	at W/2	-1	-0.7	-0.3	-0.27
	H&L Apply	-0.5	0.7	-1.2	-1.08
	At Remainder	-0.5	-0.7	0.2	0.18
Local Pressure	-2	0.7	-2.7	-2.43	
Coefficient(Cpe)	-2	-0.7	-1.3	-1.17	

Wind load coefficient for cladding as shown in Table.2

Table.2 Wind pressure coefficient for Cladding at θ=0°

Surface	Cpe	Cpi	(Cpe-Cpi)	(Cpe-Cpi)*A*Pd
A	0.7	0.7	0	0
	0.7	-0.7	1.4	1.26
B	-0.3	0.7	-1	-0.9
	-0.3	-0.7	0.4	0.36
C	-0.7	0.7	-1.4	-1.26
	-0.7	-0.7	0	0
D	-0.7	0.7	-1.4	-1.26
	-0.7	-0.7	0	0
Local	-1.1	0.7	-1.8	-1.62
Cpe	-1.1	-0.7	-0.4	-0.36

Table.3 Wind pressure coefficient for cladding at θ = 90°

Surface	Cpe	Cpi	(Cpe-Cpi)	(Cpe-Cpi)*A*Pd
A	-0.5	0.7	-1.2	-1.08
	-0.5	-0.7	0.2	0.18
B	-0.5	0.7	-1.2	-1.08
	-0.5	-0.7	0.2	0.18
C	0.7	0.7	0	0
	0.7	-0.7	1.4	1.26
D	-0.1	0.7	-0.8	-0.72
	-0.1	-0.7	0.6	0.54
Local	-1.1	0.7	-1.8	-1.62
Cpe	-1.1	-0.7	-0.4	-0.36

b) Gust factor:- Gust factor are considered as per IS:875 (Part-3)-1987 (c.l. 8.3)

Fz = Cf*Ae*Pz*G

Pz = 0.29 kN/Sq,mt

G = 4.46

Ae = 0.2 Sq.mt

Cf = force coefficient,

Deg	Cfn	Cft
0°	1.4	0
90°	0	2.2

Fz = 0.36 kN/mt for 0° (Cfn)

Fz = 0.9 kN/mt for 90° (Cft)

iv) Earthquake load calculations

Seismic force considered as per IS:1893 (1)-2002

- Seismic zone - Vadodara (Zone- 3)
- Category - 2 (Table-5 ,P# 14,IS:1893(4)-2005)
- Vb = Ah* W
- Ah = (Z/2)*(I/R)*(Sa/g)
- Z = 0.16 (Zone- 3)
- I = 1.75 (Table- 2, P# 8, IS- 1893(4)-2005
- R = 4 (Table-3 , P#9, IS-1893(4)-2005
- T = 0.085(h)^0.75
- h = 9.7 mt
- T = 0.4672 s
- Sa/g = Type- 2 , Medium Soil
- Sa/g = 2.5
- Ah = 0.0875
- Seismic weight of the building (W) = 154.79
- Vb = 13.54 kN

v) Temperature Load :- Temperature near the furnace facility is taking as 60°C. The average temperature is considered as 30°C. Hence temperature changes considered as 30° C for beam members for axial force.

vi) Load Combinations:- Load combinations considered as per IS:800-2007

The loads are calculated & assigned in the STAAD. Pro model . The existing steel facility is analysis & Designed as per NDTs & Latest codal provisions. Analytical model in STAAD.Pro as shown in fig.3

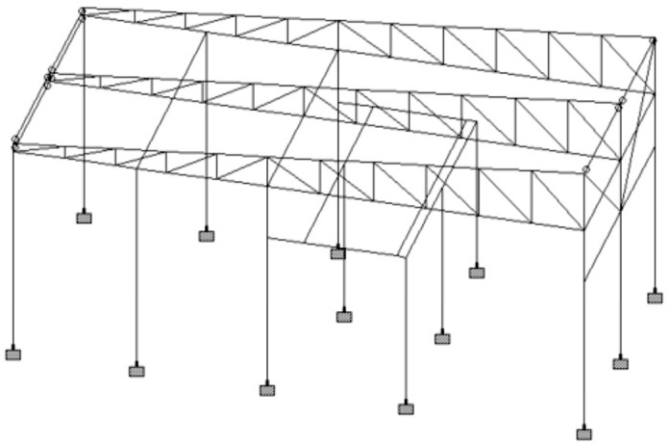

Fig.3 Existing steel facility modeled in STAAD.pro

After the Analyze & designed as per NDTs data & IS:800-2007 the comparative of study the different design methodology were done. Such as

1) Case-1 Analysis of existing structure & designed as per IS:800-1984
2) Case-2 Analysis of existing structure & designed as per IS:800-2007
3) Case-3 Analyze & designed as per NDTs + IS:800-2007
4) Case-4 Analyze & designed as per NDTs + IS:800-2007 + Strengthening measures.

The strengthening measures are taking using additional columns near the 5Tone gantry at Grid B1 as shown in figure. The deficient gantry beams with higher sections . Truss members are also strengthened by providing double angle sections. The comparative study is done for checking the stress utility ratios of the structural members with different design method. And also calculate the quantity of the structural steel after refurbishment in the steel facility as per latest codal provisions.

RESULTS

1) Non-Destructive Testing results

a) Hardness test data as shown in following Table.5

Hardness Tests Data	
Members	**Fyld (minimum) kN/Sq.mt**
ISMC 200	275000
ISMC 150	309000
ISMC 75	287000
ISMC 100	251000
ISMB 250	240000
ISMB 400	297000

b) Ultrasonic thickness measurements results:

i) ISMC 100 is reducing their thickness by 14.90 % from original thickness.

ii) ISMB 250 is reducing their thickness by 37.60 % from original thickness.

iii) ISMB 400 is reducing their thickness by 25.00 % from original thickness.

c) Coupons test shows that the initial strength of the structural members is 350 N/ Sq.mm.

2) Analytical observations

The research study have found the results regarding the analysis and design of the different cases as shown in the Table 6

Table :6 Analytical Observations

Analytical Observations				
Sr.	**Description**	**Case-1**	**Case-2**	**Case-3**
No	**Members**	**Utility**	**Utility**	**Utility**
	Details	Ratio	Ratio	Ratio
1	ISMC 200	1.27	1.89	2.794
2	ISMC 150	0.815	2.32	2.437
3	ISMC 100	1.328	10.2	21.164
4	ISMC 75	1.57	1.68	1.97
5	ISMB 400	1.887	1.713	3.52
7	ISMB 250	1.14	0.625	1.305
6	ISMB 200	1.324	2.34	3.176
7	ISA 50X50X5	9.021	8.683	9.021
8	ISA 50X50X5 SD	1.87	2.75	3
9	ISA 40X40X5 SD	3.96	4.35	4.6

The analytical results shows that the following results for the structural members in the steel facility.

a) As per results of the case -1, it's seems that the columns are failing under the combined stress such as axial compression & bending. And the flexural members were failing due to slenderness, similarly many beams are failing under deflection. Many members of the truss are also fail in the slenderness .

b) As per results of the case-2 , the clumn are fail under the combined actions of bending & axial compression. Beams are also failing under the bending & axial compression.. The compressive strength of the truss members in the facility are not taking design loads.

c) The NDTs data seems to reduced in the residual strength of the many existing structural members in the facility and also reduced in the residual thickness of the beams near the furnace facility due to temperature variations. Hence many structural members are design deficient as per NDTs data & as per latest codal provisions.

The results showed that the existing structural members in the steel facility is designed deficient as per current codal provisions. Hence the strengthening measurements are required in the existing structural members in the steel facility to its extended life span.

The steel facility is strengthened as per Retrofitting and repair is now fulfills their criteria as per latest codal requirements to its extended life span. The structural steel quantity is increased to 20.4 Tons from 7.6 Tons. There are increased in the quantity of structural steel after the refurbishment of the existing steel facility by 12.85 Tons.

2) Field observations:

a) The Members in the Existing Steel Facility is Heavily Corroded. Pitting is Taking Place on the Surface. Excessive Dent Mark on the Surface. As shown in fig.4

Fig.4 Corroded members in the facility

b) The deflection is take place in existing structural members. As shown in fig.5

Fig:5 Deflection in the column

c) The Member Above the Furnace is Heavily Affected due to temperature changes n the Facility. Figure:4 shows the Member which is Affected due to Temperature Changes. The thickness of This Member is Lost due to Temperature. As shown in fig.6

Fig:6 Corroded member in the steel facility due temperature changes

DISCUSSION

The results of the Current research work showing the utility ratios of the structural members of the steel facility as per various design method.

1) The utility ratios of the structural members increased with designed as per latest codal provisions i.e. IS:800-2007

2) The steel structure facility have deteriorated as time passes and hence their residual strength is reduced, therefore the structural members of existing steel structure facility have reduced their strength capacity. hence the utility ratios of their structural members are increased.

3) The design deficient steel facility is requires larger sections and additional members hence their total quantity of steel are increased with larger amount.

CONCLUSION

1) The current research work is conducted on the existing steel facility, And it is analysis & designed as per latest codal provisions and using NDTs data. It shows that the utility ratios of the structural members of the steel facility are increased with respect to IS:800-1984.

2) Furthermore the existing steel facility is assessed as per NDTs & latest codal provisions are deficient and the utility ratios of the structural members are increased .

3) Hence the existing steel facility which were designed as per IS:800-1984 that showing design deficient as per current codal provisions. Hence it requires strengthening as per current codal provisions to its extended life span.

4) There are increased in the structural steel quantity when strengthening measurements are provided. Hence the Condition assessment of the existing steel structure facility is required as per latest codal provisions & NDTs.

REFERENCES

1. ADINDA Chaerany, A. A. (2012). Structural Condition Assessment of Steel-Framed Maintenance Plant in Muara Badak, Balikpapan, East Kalimantan, Indonesia. Applied mechanics & Materials , 345-355.
2. AISC. (2002). AISC rehabilitation and retrofit guide series 15. American institute of steel construction inc.
3. Eric Wey, B. D. (2012). Repair and retrofit of opened frame steel structures. Structure congress, ASCE , 1236 TO 1246.
4. IS 1893 (Part-4)-2004. (2005, august). Part-4 Industrial structures including stacklike structures,Criteria of earthquake resistant design of structures . India: Bureu of Indian Standards.
5. IS:1608-2005. (2005). Metalic materials - Tensile testing at ambient temperature. New delhi: Bureu of Indian standards.
6. IS:1893 (Part 1)-2002. (2002, june). Part-1 General provisions & buildings,Criteria of earthquake resistant design of structures . India: Bureu of Indian standards.
7. IS:800. (1984). IS:800-1984. Bureau of Indian standard.
8. IS:800. (2007). IS:800-2007. GENERAL CONSTRUCTION IN STEEL-Code of practice . New Delhi, India: Bureau of Indian standard.
9. IS:875 (Part-1)-1987. (1987). Part-1 Dead Loads,Code of practice for design loads(other than earthquake) for buildings & structures . India: Bureu of Indian standards.
10. IS:875 (Part-3)-1987. (1987). Part-3 Wind Loads, Code of practice for design loads for buildings & structures . India: Bureu of Indian standards.
11. IS:875 (Part-5)-1987. (1987). Part-5 Special Loads & combinations Code of practice for design loads for buildings & structures . India: Bureu of Indian Standard.
12. IS:875(PART-2)-1987. (1987). Part- 2 Imposed loads,Code of Practice for design Loads for buildings & structures (. India: Bureu of Indian Standards.
13. N.subramanian. (2000). Restoration of cold storage factory building. journal of performance of constructed facility , 155-159.
14. N.subramanian. (2012). Steel structures, Design & Practice. New delhi: Oxford Publications.